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SPIN EFFECTS IN DIFFRACTIVE CHARMONIA PRODUCTION

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We consider exclusive double diffractive production of polarised axial-vector $\chi_c(1^+)$ and tensor $\chi_c(2^+)$ charmonia in proton-(anti)proton collisions at Tevatron energy. The corresponding amplitudes for these processes are derived within the k_t -factorisation approach. Contributions from different polarisation states of axial-vector and tensor charmonia are quantified. Corresponding experimental consequences are discussed.

Keywords: central exclusive production; k_t -factorisation; spin effects.

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1. Introduction

Recently, the central exclusive charmonia production has attracted a lot of attention from both experimental [1] and theoretical [2] sides. Such a process provides the unique opportunity to test the QCD diffractive Khoze-Martin-Ryskin (KMR) mechanism [3] based on k_t -factorisation incorporating nonperturbative small- x/k_t gluon dynamics described by the unintegrated gluon distribution functions (UGDFs) against accessible data.

The goal of the present paper is to analyze polarisation effects in the central exclusive charmonia production. Such effects can be identified potentially by measuring the angular distribution of J/ψ mesons from radiative decays of $\chi_c(J^+)$ giving more detailed information on partial spin contributions. Moreover, certain combinations of polarisation observables can be less sensitive to unknown nonper-

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turbative effects leading to unique opportunities for model-independent analysis of diffractive processes.

2. Central exclusive production of polarised axial-vector and tensor charmonia

According to the Khoze-Martin-Ryskin approach (KMR) [3], we write the amplitude of the exclusive double diffractive color singlet production $pp \rightarrow pp\chi_{cJ}$ as

$$\mathcal{M}_{J,\lambda}^{g^*g^*} = \frac{s}{2} \frac{\pi^2 \delta_{c_1 c_2}}{N_c^2 - 1} \Im \int d^2 q_{0,t} V_{J,\lambda}^{c_1 c_2} \frac{f_{g,1}^{\text{off}}(x_1, x'_1, q_{0,t}^2, q_{1,t}^2, t_1) f_{g,2}^{\text{off}}(x_2, x'_2, q_{0,t}^2, q_{2,t}^2, t_2)}{q_{0,t}^2 q_{1,t}^2 q_{2,t}^2} (1)$$

where $f_{g,i}^{\text{off}}(x_i, x'_i, q_{0,t}^2, q_{i,t}^2, t_i)$ are the off-diagonal unintegrated gluon distributions for “active” gluons with momenta $q_i = x_i p_i + q_{i,t}$ and color indices c_i , and the screening soft gluon with small fraction $x' \ll x_i$, $q_0 \simeq q_{0,t}$, J and λ are the spin and helicity of a produced meson with momentum $P = q_1 + q_2$ and mass M in the center-of-mass frame of colliding protons and z axis directed along the meson momentum \mathbf{P} , respectively. Hard subprocess parts $V_{J,\lambda}^{c_1 c_2}(g^*g^* \rightarrow \chi_c)$ were calculated previously in Refs. [4], and we will not shown them explicitly here.

In Fig. 1 we show differential distributions of the central exclusive $\chi_c(1^+)$ (left) and $\chi_c(2^+)$ (right) production cross section in rapidity y for different meson polarisations $\lambda = 0, \pm 1, \pm 2$ (calculated with KMR UGDF [5]). They exhibit maxima/minima in the central rapidity region $y \sim 0$. Interestingly enough, these maxima/minima in partial helicity contributions cancel each other in the total (summed over all meson helicity states) cross section, which has a regular and smooth behavior around $y \rightarrow 0$. The cross section integrated over all possible meson rapidities y

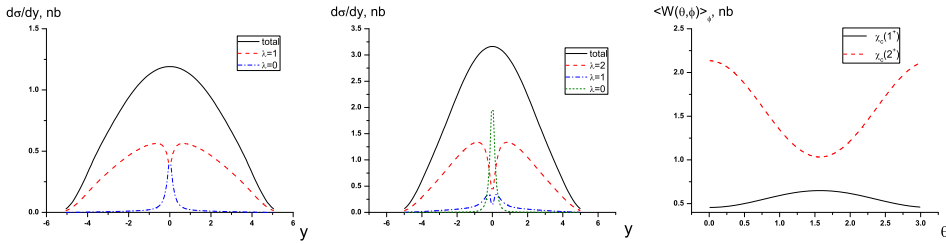


Fig. 1. Distributions of the CEP cross section in rapidity y of $\chi_c(1^+)$ (left) and $\chi_c(2^+)$ (middle) mesons for different polarisation states. In the right panel the distribution of outgoing J/ψ meson in the polar angle θ averaged over azimuthal angle ϕ is also given for $\chi_c(1^+)$ (solid line) and $\chi_c(2^+)$ (dashed line) mesons. KMR UGDF is used.

(in our case $|y| \leq 6.0$) is dominated by maximal meson helicity contributions, i.e. by $|\lambda| = 1$ for $\chi_c(1^+)$ and by $|\lambda| = 2$ for $\chi_c(2^+)$. This confirms that the appearance of non-maximal helicities is a kinematical effect absent in the spin-averaged cross-section. We do not take into account the absorptive effects here as they can, in principle, differ for different meson polarisations.

3. Angular distribution of J/ψ meson

Let us consider the central exclusive production process $pp \rightarrow pp\chi_{cJ}$ followed by the radiative decays $\chi_{cJ} \rightarrow J/\psi + \gamma$. Below we follow notations in Ref. [6]. Let θ and ϕ be the polar and azimuthal angles of the J/ψ meson in the respective coordinate system of $\chi_c(J^+)$ rest frame (this is so-called helicity frame). Then, the angular distribution of the J/ψ meson from $\chi_c(1^+)$ meson in the general form reads

$$W^{J=1}(\theta, \phi) = \frac{3\sigma_{\chi_c}^{J=1}}{4\pi} \left\{ \rho_{0,0}^1 \left[r_0^1 \cos^2 \theta + \frac{r_1^1}{2} \sin^2 \theta \right] + \rho_{1,1}^1 \left[r_0^1 \sin^2 \theta + \frac{r_1^1}{2} (1 + \cos^2 \theta) \right] \right. \\ \left. - \sqrt{2} \sin(2\theta) \left(r_0^1 - \frac{r_1^1}{2} \right) [\text{Re}(\rho_{1,0}^1) \cos \phi - \text{Im}(\rho_{1,0}^1) \sin \phi] \right. \\ \left. - \sin^2 \theta \left(r_0^1 - \frac{r_1^1}{2} \right) [\text{Re}(\rho_{1,-1}^1) \cos(2\phi) - \text{Im}(\rho_{1,-1}^1) \sin(2\phi)] \right\}, \quad (2)$$

where $\rho_{\lambda\lambda'}$ are the diffractive production density matrix, $\sigma_{\chi_c}^{J=1}$ total (summed over all meson polarisations λ) production cross section, and $r_0^1 \simeq r_1^1 \simeq 0.5$. Corresponding expression for tensor $\chi_c(2^+)$ meson is much more complicated, and we do not show it here.

Function $W(\theta, \phi)$ is a periodic one in both angles θ and ϕ . From Eq. (2) it follows that dependence on the polar angle θ is determined mostly by diagonal terms of the production density matrix $\rho_{\lambda\lambda}^J$, whereas ϕ -dependence is given by real and imaginary parts of non-diagonal terms. Periods of oscillations in polar angle θ for $\chi_c(1^+)$ and $\chi_c(2^+)$ mesons are shifted by $\pi/2$ with respect to each other, as demonstrated in Fig. 1 (right) for distribution $\langle W(\theta, \phi) \rangle_\phi$ averaged over ϕ .

4. Conclusions

We have calculated differential cross sections for central exclusive $\chi_c(1^+, 2^+)$ meson production for different spin polarisations. The integrated cross section for the maximal helicity state is approximately an order of magnitude greater than that for the non-maximal ones. We have calculated, in addition, angular distributions of J/ψ meson $W^J(\theta, \phi)$ from radiative decays $\chi_c(1^+, 2^+) \rightarrow J/\psi + \gamma$. Function $W^J(\theta, \phi)$ contains information about all independent elements of CEP density matrix.

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